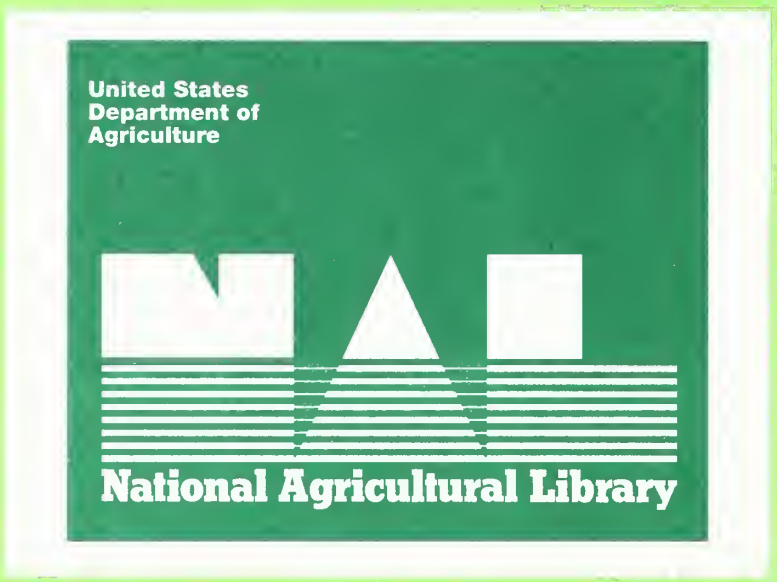
VEGETATION AND MECHANICAL SYSTEMS

"For Streambank Erosion Control"

"Guidelines For Streambank Erosion Control Along The Banks of the Missouri River From Garrison Dam Downstream To Bismarck, North Dakota"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The guidelines for Streambank Erosion Control along the Banks of the Missouri River from Garrison Dam to Bismarck, North Dakota were produced through a Memorandum of Understanding between the

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and the

North Dakota State Forest Service

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One:

Conclusions/Recommendations

1. Sites that are revegetated need to be sloped to a specific angle, no steeper than 1 vertical to 1 horizontal.

2. Topsoil needs to be stockpiled and replaced or imported on the site to a depth of 4 inches. Fertilizer may need to be added.

3. Plant materials need to be genetically adapted to the site.

4. A community of plants needs to be re-established, not a monoculture.

5. Specific sites will need specified plant species.

6. Plant materials must be handled, stored and planted properly so that live, healthy plants are correctly planted.

7. Some site situations are more critical for revegetation than others.

8. Monitoring of the plantings and site erosion should be done for a minimum of 3 years.

9. Management of the re-established plant community is necessary.

Two:

Procedures

Two extensive library searches 1/ were made for published information on the reach of the Missouri River from Garrison Dam to Bismarck,North Dakota, relative to vegetation and streambank erosion control 2/.

An Interdisciplinary Team (I.D.) of Scientists 3/ assembled at North Dakota State University January 30-February 2, 1979 and, through their interdisciplinary efforts, this document was prepared. This team used the references from the library search, other publications brought with them to the meeting, and the varied education, training and field experience and individual talents to complete this document. An extensive review process was utilized to allow each individual to critically review the draft document and input into the final document.

1/ Westfornet computerized library search system
2/ See bibliography
3/ See Biographical Data

Three:

Introduction

OBJECTIVE

To provide generalized vegetative guidelines to assist planners in developing engineering project design and contract specifications for streambank erosion control. The stabilizing plant communities will generally be self-substaining and require a minimum of maintenance while providing streambank erosion control, esthetic, wildlife and human benefits.

SCOPE

These guidelines provide information on various engineering structures used in erosion control, site differentation, site preparation for revegetation, species to be used in revegetation, revegetation techniques, cost of revegetation materials and project monitoring.

SITE DESCRIPTION

These guidelines apply to the water-land interface and adjacent riparian area along the Missouri River from Garrison Dam (47° 30' N, 101° 27' 30" W) on the north to the back-up waters of the Oahe Reservoir, roughly approximating the northern boundary of Emmons County (46° 36' 30" N, 100° 37' 30" W). This includes approximately 80 river miles (See Figure 1). Johnson et al. (7) 1/

The Northern Great Plains lies within a climatic regime described as dry subhumid Mesothermal, Johnson et al. (7). The average annual precipitation is substantially less than potential evapotranspiration. This generally restricts the deciduous forest to low ground where soil moisture conditions are favorable. This region is subject to great fluctuations in weather conditions.

The climate of Burleigh County,North Dakota is typical of the area covered by this report. The relative humidity and rainfall are low. There is an abundance of sunshine, moderate snowfall and the prevailing winds are northwesterly. The diurnal and seasonal extremes of temperature are pronounced. The average frost free growing season runs from the first week in May to the last week in September. The mean annual precipitation is 16.5 inches, 70 percent of which occurs during the growing season, with 50 percent from May through July. The driest months are December, January and February when 0.5 inches are received as snow.

For Bismarck the mean frost free period is 136 days, the mean annual precipitation is 16 to 17 inches, the mean total hours of sunshine is 2,700 hours, the mean number of days with a maximum temperature of 90°F or greater is 23 days and the mean number of days with a minimum temperature of 32°F or less is 186 days. (20)

The west-central portion of North Dakota is included in the Glaciated Missouri Plateau section of the Great Plains Province, Fenneman (31). The Glaciated Missouri Plateau is divided into four regions: Coteau du Missouri, the Missouri Trench and two unnamed sections. The area that these guidelines apply to is within the Missouri Trench. The Missouri River floodplain varies in width from less than 1 mile at the northern

1/ Numbers in Parenthesis refer to references in the Bibliography

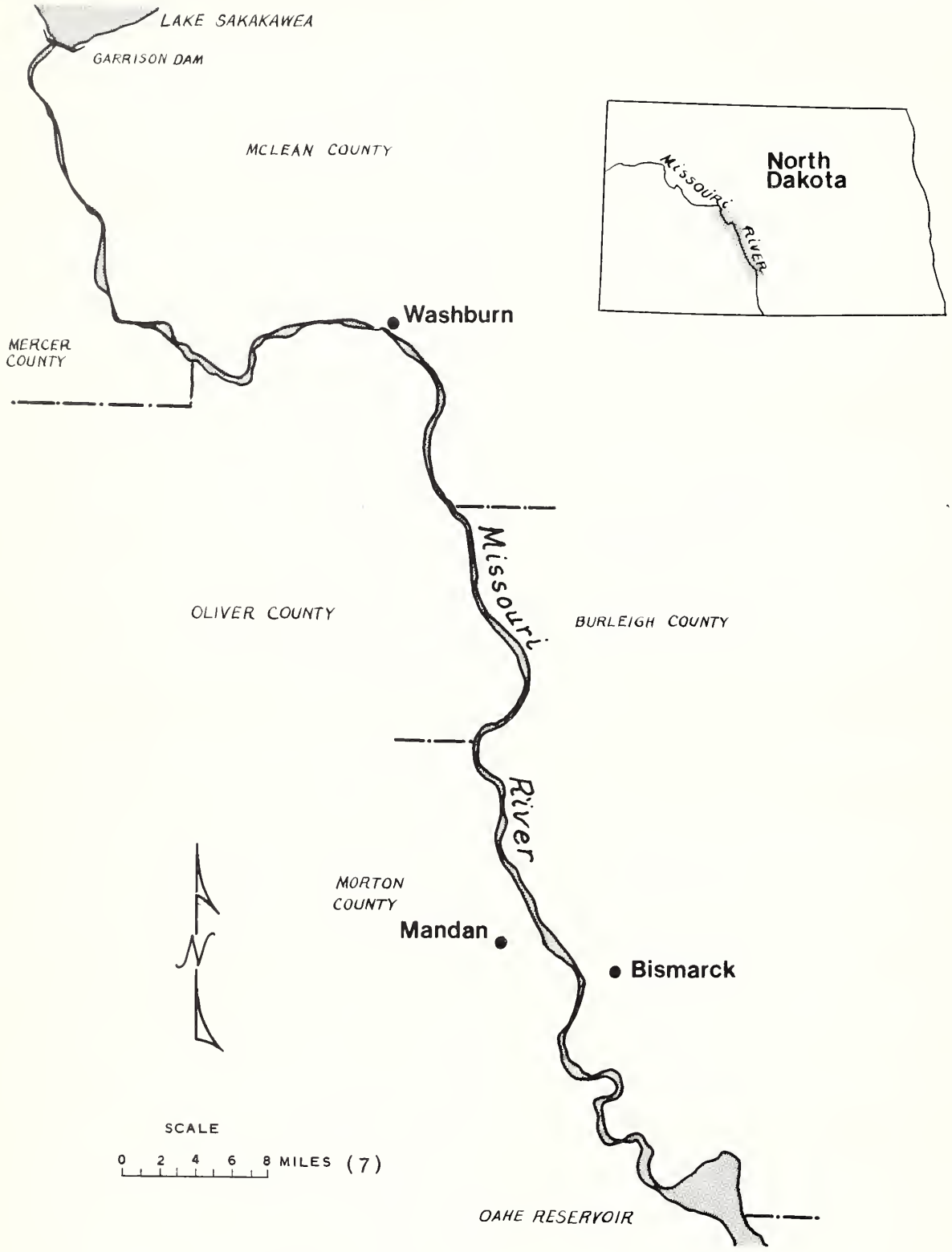


Figure 1: Vegetation Management Area

end near Garrison Dam to more than 7 miles just south of Bismarck. The river is a meandering one. Sediments settle out of the water in the Garrison Reservoir and the water released from the Garrison Dam is capable of picking up considerable sediment or in other words, is an extremely erosive force upon leaving the Garrison Dam.

The Missouri River Valley is underlain by the Hell Creek and Fox Hills formations of Cretaceous age. Superimposed on the Hell Creek formation are the Tullock and Ludlows, Cannonball and Tongue River formations of Tertiary age, which are exposed on the steep and dissected valley walls. The Sentinel Butte formation of Tertiary age is exposed near the Garrison Dam. The Missouri River Valley has well developed tributaries from the west, including the Knife, Heart and Cannonball rivers and underdeveloped tributaries from the east including Painted Woods, Snake, Burnt, Apple and Badger creeks. Therefore the Missouri River Valley floor consists of alluvium outwash and bedrock terraces. The layering of alluvium and outwash at various times is quite evident in the river cuts.

The soils of the area have formed in recent alluvium which ranges from sand to silty clay loam in texture, Omodt et al. (32). Alluvial soils usually have a grayish brown A horizon and a light grayish brown C horizon. Numerous layers of sediment often make up the soil profile, each layer deposited by a different flood. These individual layers often differ from each other in color, texture or both.

The four basic soil series present on the floodplain of the river are the Banks, Havre, Lohmiller and Gallatin.

The Banks series is found near present or former stream channels. These soils are excessively drained and are developed from course-textured recent alluvium. Sand and loamy sand are the dominant textures throughout the profile, but occasionally thin layers of loam or fine sandy loam occur. Color ranges from very dark grayish brown to brownish gray. Available water capacity is low and fertility is limited.

The Havre series usually occurs farther from the present river channel than the Banks series. Havre soils develop from medium to moderately fine-textured, calcareous, recent alluvium. Flood-deposited layers are usually medium textured,but layers of fine sandy loam, loamy sand amd silty clay are not uncommon. Color ranges from dark grayish brown to light brownish gray. Soils in this series are moderately permeable and have a high available water capacity.

The Lohmiller series is found on terraces some distance from the rivel channel. Soils comprising this series are usually moderately fine to fine silts and clays.

Soils of the Gallatin series form on poorly drained depressions and abandoned channels on the floodplain. Large amounts of fine and very fine clay particles are often a textured feature.

The soils of the floodplain have been only slightly modified by vegetation. Post flooding has continually removed or covered organic matter, lessening the effect of vegetation on soil formation. All of the soils of the floodplain are highly erodible.

At present, both prairie and forest vegetation occupy the steep valley walls rising above the Missouri River floodplain. Green needle-grass

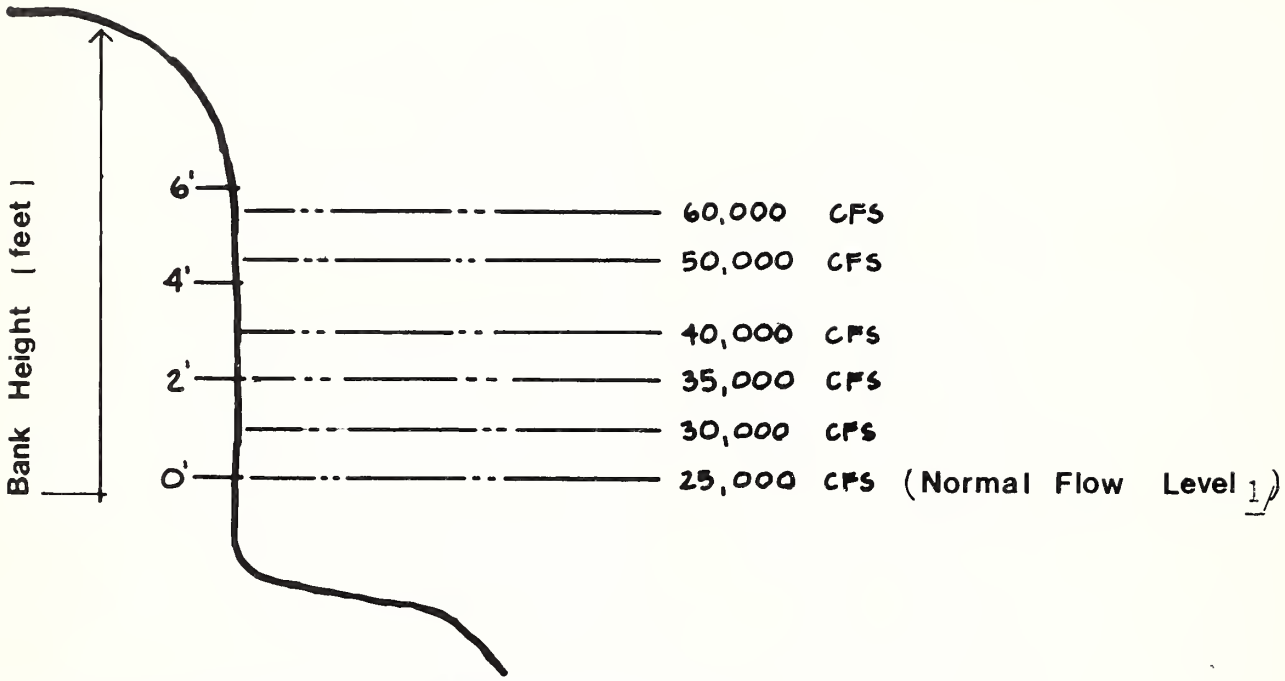


Figure 2: River Levels and Flows

Table 1: Recurrence Interval by Discharge and Duration

Discharge	Duration			Probability Of Not Ocurring (60days)
	6 Mo.	60 Days	1 Day	
60,000 CFS	-	1/100 Yrs.	1/20 Yrs.	99%
50,000 CFS	1/100	1/10	1/5	90%
40,000 CFS	1/10	1/3	1/2	67%
35,000 CFS	1/3	1/2	1	50%
30,000 CFS	1/2	1	1	1%
25,000 CFS	1	-	-	-

1/ (Normal Flow Levels) - occurs generally from April 15 - May 15 until Nov. 15
CFS = Cubic feet per second

(Stipa viridula), needle-and-thread (Stipa comata), little bluestem (Andropogon scoparius), western wheatgrass (Agropyron smithii), side-oats grama (Boutelova curtipendula) and blue grama (Boutelova gracilis) are the most common grasses in moderate to well-drained prairies. On wet prairie sites, big bluestem (Andropogon gerardi), little bluestem (Andropogon scoparius), switchgrass (Panicum virgatum), and Canada wild-rye (Elymus Canadensis) are common grasses. In wooded ravines Bur Oak (Quercus macrocarpa), green ash (Fraxinus pennsylvanica) aspen (Populus tremuloides), box elder (Acer negundo) and American Elm (Ulmus americana) are the most common.

The floodplain currently is a mosiac of cultivated fields, marshes, sand dunes, sand bars, brushland and forest. Corn,wheat, oats, sugar beets and alfalfa are common crops. The forests of the floodplain consist of mainly cottonwood (Populus deltoides), peach-leaved willow (Salix anhygdaloides), green ash (Fraxinus pennsylvanica), box elder (Acer negundo), American elm (Ulmus americana) and bur oak (Quercus macrocorpa). These floodplain forests vary depending upon their age. Young forests consist mainly of willows and cottonwoods. The willows are gradually replaced by box elder and green ash and ultimately mature floodplain forests consist of cottonwood, green ash, American elm and bur oak.

The prairie on the floodplain river is similar to the wet prairie discussed above. Marshes dominated by sedges (Carex spp.) and cattails (Typha spp.) are found in old stream channels.

The Missouri River readily erodes the river bank no matter what the vegetation or the land use is along the river. The eroded banks vary from a few feet to steep banks 15-20 feet high. This erosion necessitates the use of engineering structures and bank vegetation to control the bank erosion.

RIVER LEVEL AND FLOW RATE

Table No. 1 shows the frequency of various flows and their duration with 25,000 cfs being the normal flow from late spring through fall. Thus a 40,000 cfs flow with a duration of 6 months can be expected to occur once every 10 years, a 60,000 cfs flow with a duration of 60 days can be expected to occur once every 100 years and a 60,000 cfs flow with a duration of 6 months should not occur.

Figure 2 shows the approximate water level corresponding to various river flows, using the level of 25,000 cfs as the reference. Thus at a flow of 40,000 cfs, the river level will be approximately 3 feet above the reference level.

Flows may be increased from the normal 25,000 cfs in June or July in order to decrease excess water stored behind the Garrison Dam before freeze up. Flows after November 15 through April 15 normally are about 15,000 cfs.

Four:

Typical Structure Design and Placement

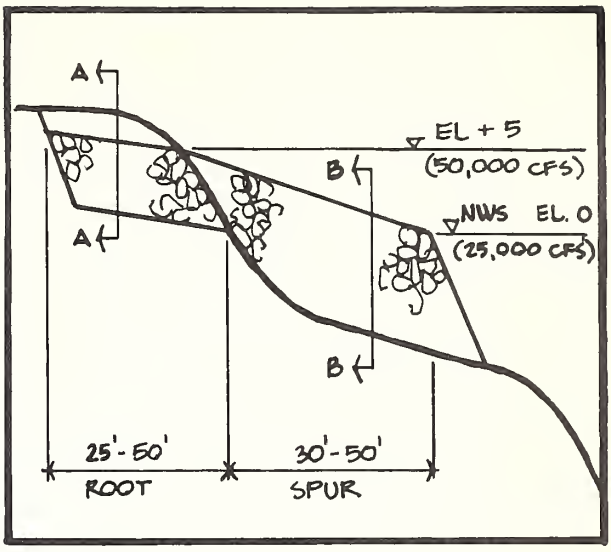
BACKGROUND

Banks of the Missouri River are easily erodible. Left unprotected, the river would continually modify its course by erosion in one area and sandbar development in another area. However, the Corps of Engineers has an established commitment to reduce the massive erosion that would occur on specific sites if the banks were left unprotected. Through extensive experience, the Corps has settled on a combination of permenant force-abating structures that are strategically located.

Two typical force-abating structures commonly used in bank stabilization are revetments and hardpoints. A revetment can be constructed from many hard materials and is placed horizonal to the bank on the "toe" of a normal discharge beach. Figure 4 illustrates the typical placement of revetments on a low and high-bank beach relative to the normal daily flow rate. A hardpoint is typically a rock filled projection extending perpendicular from the bank and is illustrated in Figure 3. In specialized cases where sandbars must be stabilized, reinforced sandfilled dikes (Figure 5) may be used.

An example of a typical demonstration structure layout on an eroding streambank is presented in Figure 6. Demonstration structure layouts intentionally leave 250 to 1,000 feet and more of unaltered bank between structures.

Demonstration structure layouts intentionally leave spaces of unaltered bank between structures. Unprotected requirements range from 250



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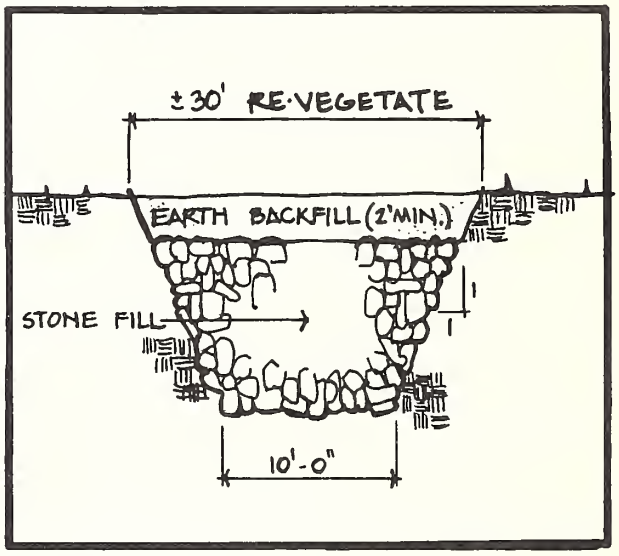
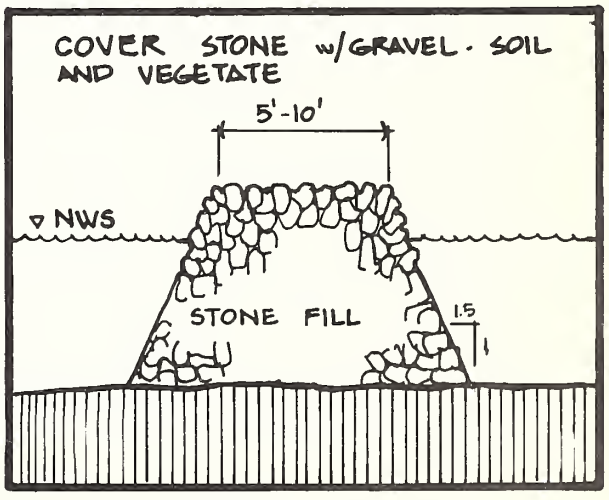
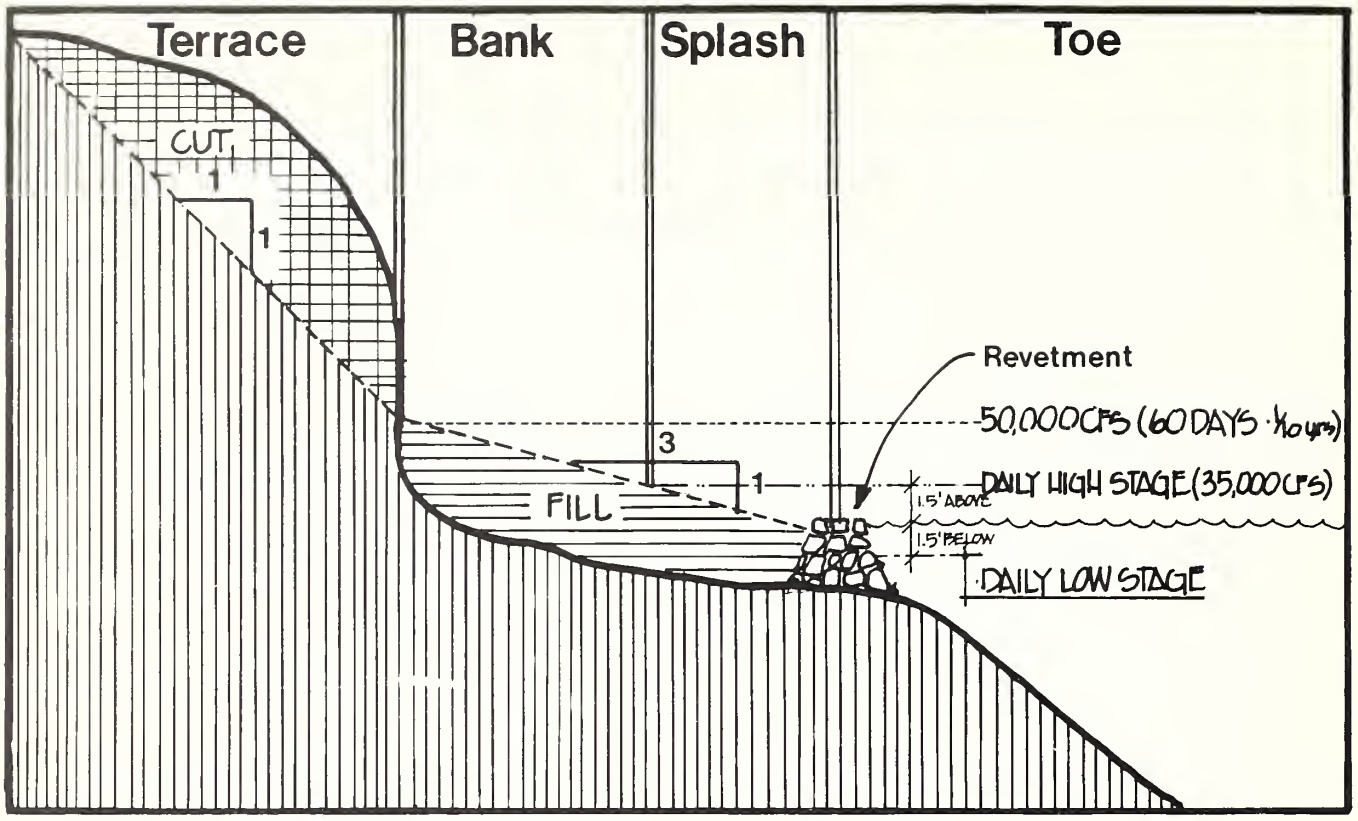


Section A-A

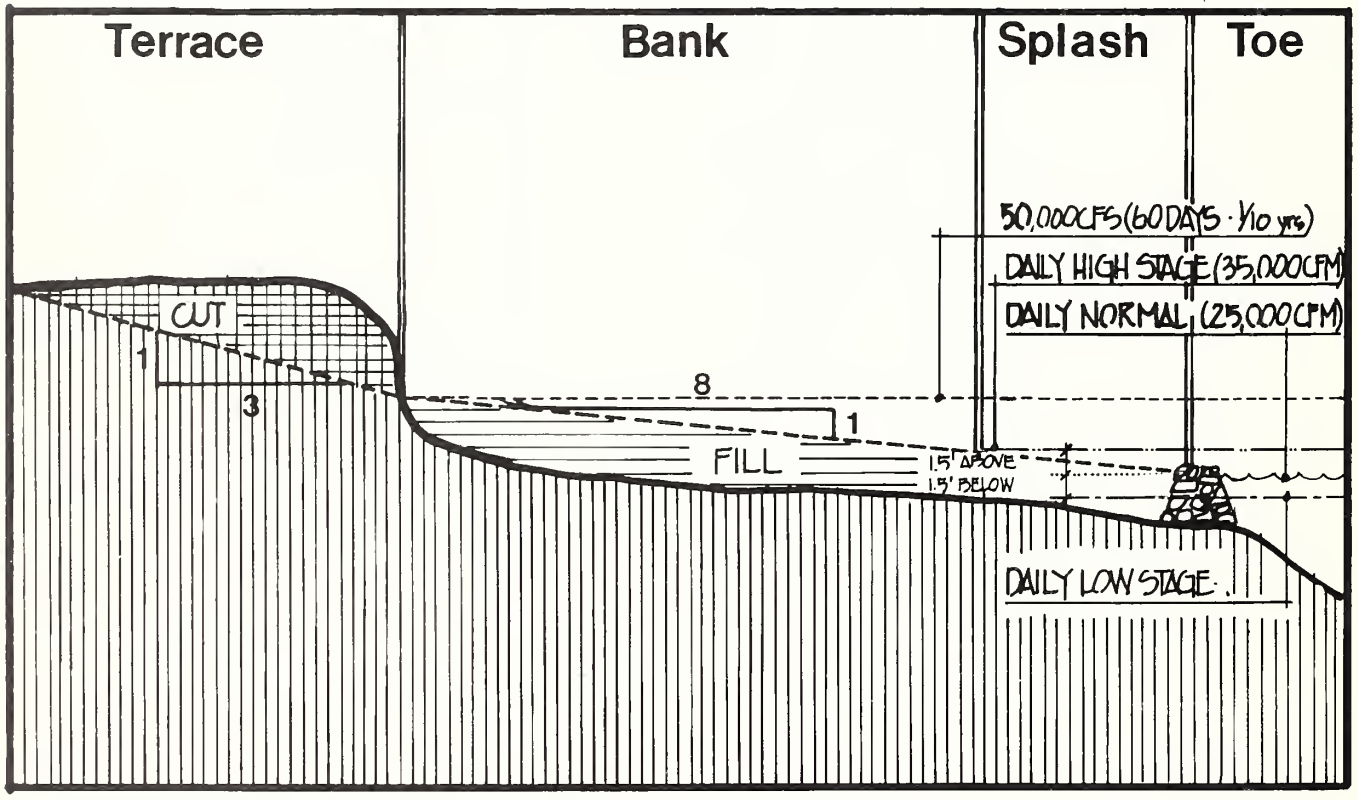


Section B-B

Figure 3: Hardpoint



1 Maximum Slope Limits . . . . . (NO SCALE)



2 Minimum Slope Limits . . . . . (NO SCALE)

Figure 4: Constructed Slopes

feet to 1,000 feet and more in length. Each structure includes a "root" (hardpoints) or "refusal" (revetments) which extends landward, perpendicular to the bank a sufficient distance to allow for the anticipated interstructure erosion. Roots and refusals generally range from 25 feet to 100 feet in length.

THEORY

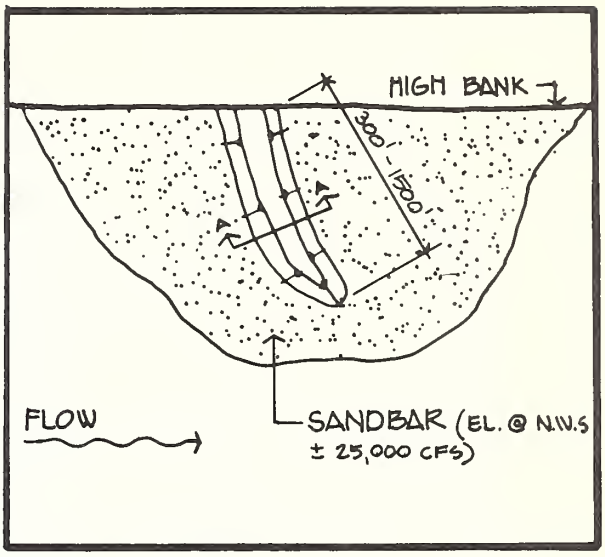
The extent of the interstructure erosion is limited by the prevailing water depth and velocity riverward of the structure alignment (the theoretical line connecting the riverward extremity of all the structures in the system); by the bank height and composition (material types); and by the structure spacing. As the river erodes into the bank, the flow path becomes longer as the water entering the erosion "bight" must return to the original bank location at the next downstream structure. Accordingly, the energy gradient becomes proportionally less as the size of the "bight" grows.

Thus, at a given river stage (discharge) the "bight" ceases to grow when the energy gradient is no longer sufficient to remove material from the bankline.

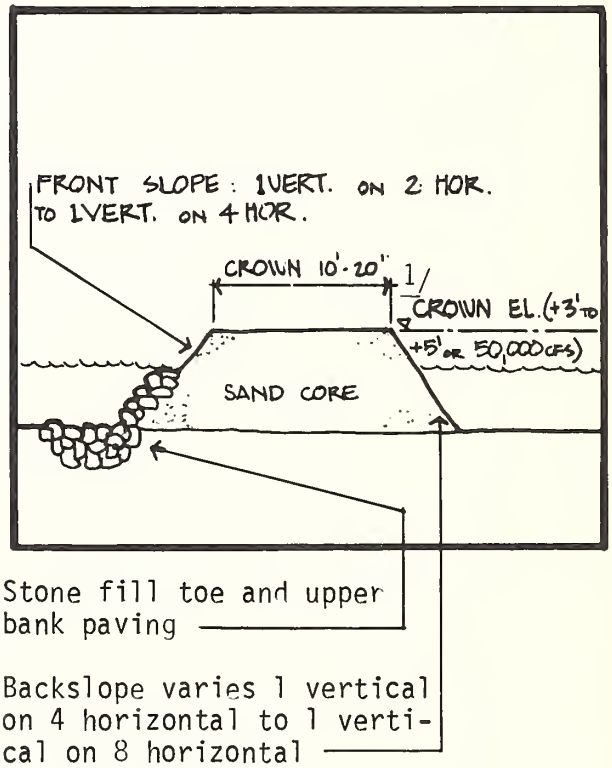
The resulting configuration and cross section of the "stable" bankline is shown in Figure 6. However, the configuration will remain stable only as long as extended duration flows do not exceed the flow-level which created that configuration.

NEED FOR VEGETATION

Planting vegetation on the banks behind revetments and on top of hardpoints are a must to stabilize easily erodible constructed slopes. These plantings should be accomplished shortly after con-



Plan



Section A-A

1/ Treat slopes and crown with combination (or singly) of stone, gravel, structural mesh and vegetation.

NOTE: Crown elevation generally level for any given structures.

Figure 5: Sandfill Dike

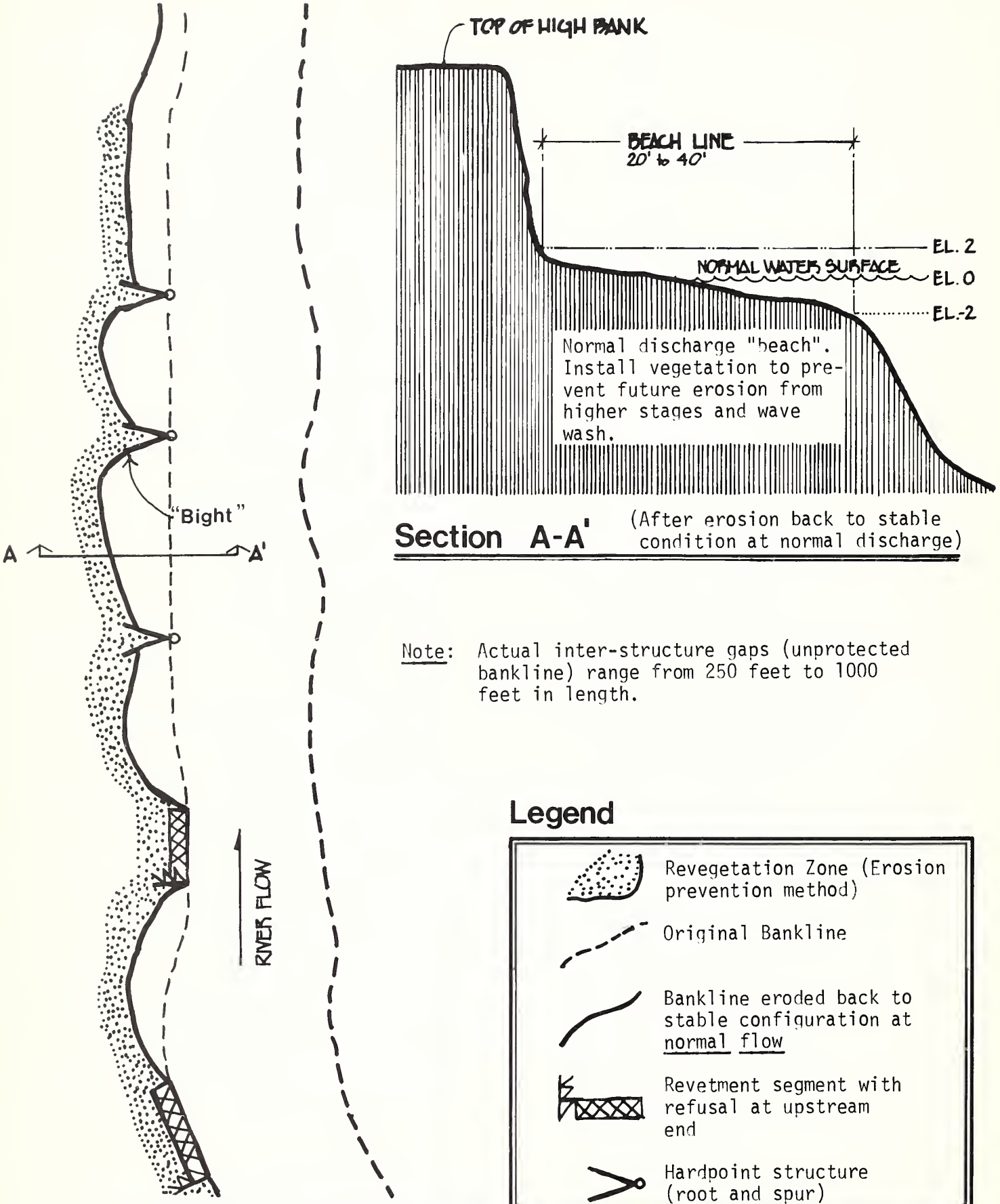


Figure 6: Structure Spacing

struction of the structure to prevent unnecessary erosion prior to planting.

Planting vegetation along the "beach" formed along the eroded bankline at normal water flow rates should reduce or prevent additional erosion at higher river stages and erosion due to wave-wash action. Such plantings may reduce the need for as many expensive structure developments by increasing the length of unprotected (except for vegetation) shoreline between structures. However, it may be necessary to delay vegetational plantings in the interstructural area until a near-stable bankline is formed. In addition, some bank grading may be necessary to allow establishment of the vegetation.

BANK ZONE DESCRIPTION

The U.S. Corps of Engineers has divided the stable bank into three zones (terrace, bank and splash zones). These zones are not precise and distinct since the river level varies daily and seasonally, but they should be useful in subsequent discussions. Figure 4 illustrates the location of each zone, the following is a description of each zone:

Splash zone - that portion of the bank between the normal high-water and normal low-water flow rates. This is the zone of highest stress. The splash zone is exposed frequently to wave-wash, erosive river currents, ice and debris movement, wet-dry cycles and freezing thawing cycles. This section of the bank normally would be inundated throughout most of the year, at least 6 months/year. The water depths will fluctuate daily, seasonally and by location within the splash zone.

Bank zone - that portion of the bank usually above the normal high-water level; yet, this site is still exposed periodically to wave-wash, erosive river currents, ice and debris movement and traffic by animals or man. The site is inundated for a 60-day duration once every 2 to 3 years (Table 1). The water table in this zone frequently is close to the soil surface due to its closeness to the normal river level.

Terrace zone - that portion of the bank from the bank zone inland which usually is not subjected to erosive action of the river except during occasional time "flooding" by the river. This zone may include only the level area near the crest of the unaltered "high bank" or may include sharply sloping soils on high hills bordering the river. The terrace zone probably will include much of the "cut" area on constructed slopes (Figure 4), especially on sharp 1 vertical to 1 horizontal slopes. This zone generally is subjected to periodic dry periods with soil moisture primarily dependent on characteristic rainfall of the area.

Five:

Site Preparation

SLOPING

River banks within the designated project areas will be treated with various combinations of structures and vegetation for protection from further erosion damages. Figure 4 indicates both maximum and minimum slope limits. For steeper banks, the cut would generally be a 1 vertical to 1 horizontal slope. For the fill area below the cut to the toe-in, the slope would generally be constructed on a 1 vertical to 3 horizontal slope.

For the more gentle sloping banks needing erosion protection, the cut slope would be about 1 vertical to 3 horizontal and the fill slope would be about 1 vertical to 8 horizontal to the toe-in.

The terrace, bank and splash zones are superimposed on these typical cross-sections to indicate their relative position to various water levels and cut and fill slopes.

Daily normal water level (25,000 cfs) generally fluctuates about 3 feet below Garrison Dam.

STOCKPILING TOPSOIL AND REPLACEMENT

In a 1960 U.S. Army Corps of Engineers study (23), the soils consisted primarily of sandy silt and silty fine sand with some clay soils at varying heights above the water surface.

A vegetation study along this stretch of river was conducted by Johnson, et al (7). The authors indicated that soil profile development is minimal with only A and C layers usually distinguishable.

Most of the soils along the river banks are highly susceptible to erosion when saturated or from wave action. Therefore, disturbed sites will erode quite readily if protection is not attained.

Recommendations:

All areas that will be vegetated should have a minimum of 4 inches of topsoil uniformily spread across the cut and fill slopes. Usually the topsoil is considered the surface soil high in organic matter. Availability of topsoil at each site will need to be determined since it may vary from 1 inch or less to several feet thick. If greater than 4 inches of topsoil is available, the contractor may choose to stockpile the topsoil for later use. However, if economics dictate or topsoil is unavailable at the site, topsoil can be imported. Imported topsoil preferably should be "black" (greater than 1.5 percent organic matter) sandy loam, loamy sand, or loam soil textural classes. The "black" soil color indicates a high organic matter essential to establishing and maintaining vigorous vegetation.

Although stands of vegetation can be established with greater difficulty and more time with other techniques, the success of bank stablization with vegetation may well depend on topsoiling.

SLOPE PROTECTION

Slope protection requirements necessary for the establishment of vegetation are dependent upon the following variables. (See Figures 3, 4 and 5).

1. Type of vegetation

2. Slope angle
3. Slope materials
4. Formation on slope relative to various flow levels.
5. Interface with structural measures.
6. Exposure to surface runoff.
7. Exposure to prevailing sun and wind directions.
8. Exposure to traffic by man and animal.

Factors 1 through 4 are particularly interdependent and can be combined into many acceptable configurations which would not require special slope treatment.

Factor 5 can possibly be utilized to eliminate the requirement for special slope treatment; for example, planting could be made through (or prior to placement of) a layer of course gravel, cobbles or even small stone.

Factor 6, surface runoff, can usually be handled by proper grading of the terrace zone to conduct surface runoff away from newly vegetated slopes and into locations where adequate drainage measures exist or can be installed.

Factor 7, adverse sun or wind exposure, will generally require special surface treatment to control surface moisture gain or loss, as appropriate.

Factor 8, pedestrian, vehicles or animal traffic, should be eliminated by fencing or other measures.

Specific measures for slope protection, when necessary, shall be part of the planting instructions for the specific site and plant types involved.

At present there is a product on the market that retains soil moisture and might be applicable for slope protection purposes. It is a hydrophobic cellulose starch known as Sorbex 200 1/. It is produced by Sorbex Products Company, Incorporated, Bismarck, North Dakota.

Also two chemicals are available that impede surface runoff. They have been tested by the Geotechnical Laboratory, U.S. Army Engineers Waterway Experiment Station, Vicksburg, Mississippi. Application of this compound for slope protection should be explored further.

1/ USDA-Forest Service does not endorse any commercial product.

Six:

Adapted Vegetation by Bank Zone

Vegetation to aid bank stabilization must be selected for the different sites encountered on the river bank. The typical bank zones (splash, bank and terrace) are described in the section on structure design and placement (pages 11 to 15). These zones are only approximate since the river level varies daily and seasonally; therefore, the area classified as the bank zone during May may be the splash zone in August when a higher daily flow rate is released from the Garrison Dam to reduce the impounded water. As a result, a community of species and specific planting patterns will be suggested to allow natural selection to differentially select the species most adapted to that specific microenvironment. In addition, only species naturally adapted to North Dakota commonly occurring in environments similar to those anticipated in each zone will be suggested. Figure 7 summarizes the most desirable species to revegetate the various bank zones. The following is a detailed discussion by bank zone of species selected

SPLASH ZONE

This section of the bank will be inundated throughout much of the year and is the zone of highest stress from river action. Plants used in the splash zone should have rhizomes (underground stems) that can regenerate topgrowth rapidly following removal by river action.

Species that commonly occur in similar environments are the submerged and emergent aquatic plants such as Typha, Scripus, Juncus, Polygonum and Phragmites. Therefore to vetetate the splash zone, it is suggested that a mixture of cattails; softstem, hardstem and American bulrush; and common reed should be planted. If additional diversity is desired in the plant community other species listed in Table 2 can be added.

BANK ZONE

The bank zone usually is above the normal water level. However, high discharge rates are to be expected causing seasonal inundation and a 60-day inundation can be anticipated once every 2 to 3 years (Table 1). The water table is fairly close to the surface even at normal flow rates due to the proximity of the river. Graded bank zones will range from 1 vertical to 8 horizontal to 1 vertical to 3 horizontal slopes and may have fill material deposited in this site. Consequently, a mixed soil condition likely will be encountered.

The bank zone in an undisturbed state will support a variety of grasses and some shrub species like willows and dogwood. In revegetating the bank zone, flood tolerant grasses like reed canarygrass, creeping foxtail and prairie cordgrass should be planted (preferably sodded) to obtain a quick cover. Shrub species like peach-leaf willow, yellow willow and red osier dogwood should be systematically planted into the grasses because ultimately these shrubs should provide most of the plant cover. If the grasses are seeded on the higher elevation bank areas, crownvetch and sweetclover should be added to the grass seed mixture to provide some soil fertility (nitrogen). Other grass and shrub species listed in Table 3 can be used to add

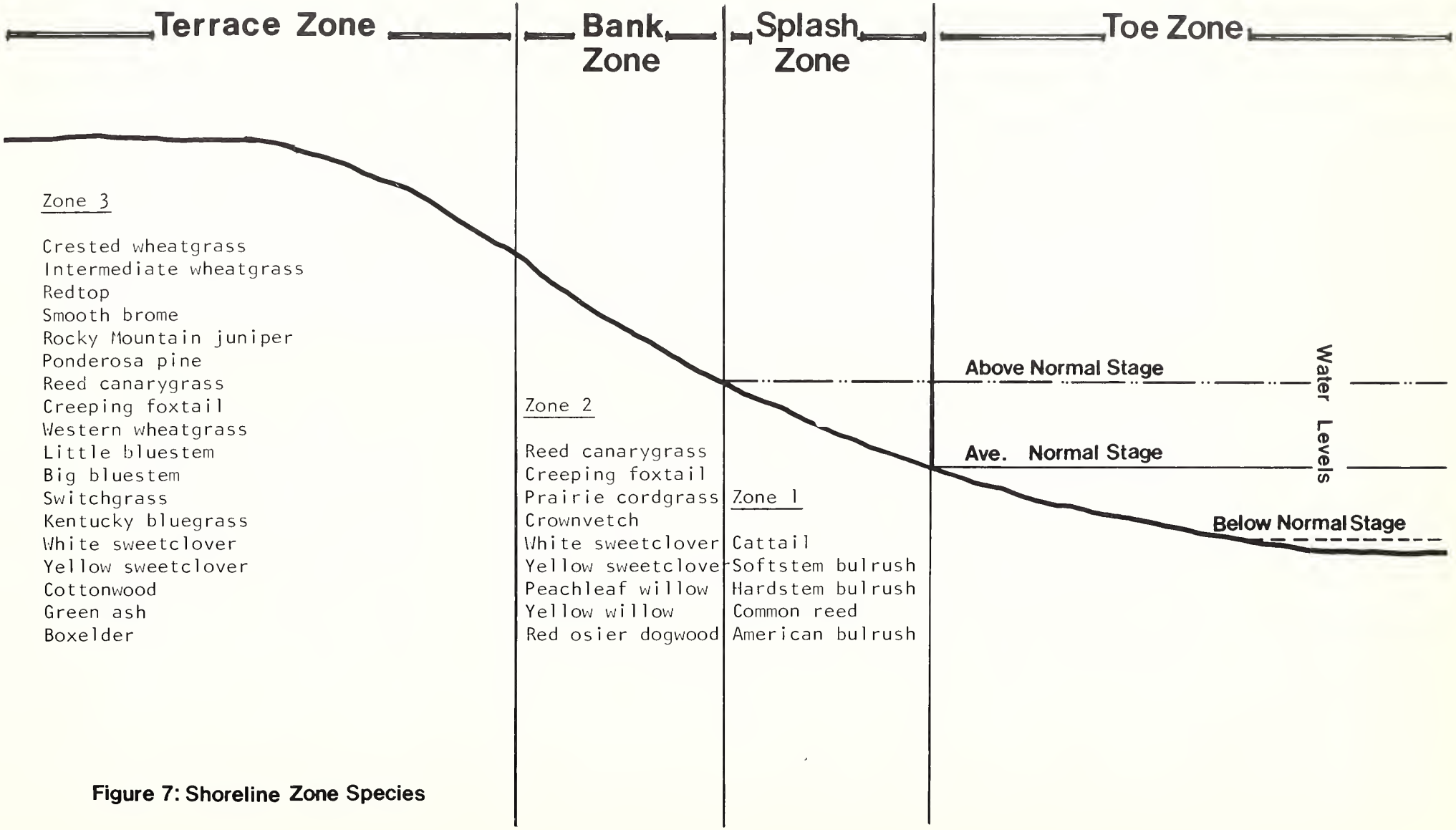


Figure 7: Shoreline Zone Species

Table 2

SPECIES RECOMMENDED FOR REVEGETATING THE SPLASH ZONE

SPECIES			
COMMON NAMES	SCIENTIFIC NAME	AVAILABILITY OF PLANT MATERIALS	METHOD OF PLANTING
Cattail	Typha latifolia	Local collection of rhizomes	Sprigging
Sofstem bulrush	Scirpus validus	Local collection of rhizomes	Sprigging
Hardstem bulrush	Scirpus acutus	Local collection of rhizomes	Sprigging
American bulrush	Scirpus americanus	Local collection of rhizomes	Sprigging
Swamp smartweed	Polygonum coccineum	Local seed collection	Seeding
Pale smartweed	Polygonum lapathifolium	Local seed collection	Seeding
Giant mannagrass	Glyceria grandis	Local seed collection	Seeding
American mannagrass	Glyceria striata	Local seed collection	Seeding
Common reed	Phragmites communis	Local collection of rhizomes & seed	Sprigging & seeding

Table 3

SPECIES RECOMMENDED FOR REVEGETATING THE BANK ZONE

SPECIES			
COMMON NAME	SCIENTIFIC NAME	AVAILABILITY OF PLANT MATERIALS	METHOD OF PLANTING
Grasses			
Reed canarygrass	Phalaris arundinacea	Commercial seed lot	Seeding, sprigging & Sodding
Creeping foxtail	Alopecurus arundinaceus	Commercial seed lot	Seeding
Northern reedgrass	Calamagrostis inexpansa	Local collection of seed & rhizomes	Seeding & sprigging
Prairie cordgrass	Spartina pectinata	Local collection of seed & rhizomes	Seeding & sprigging
Meadow fescue	Festuca elatior	Commercial seed lot	Seeding
Legumes			
White sweetclover	Melilotus alba	Commercial seed lot	Seeding
Yellow sweetclover	Melilotus officinalis	Commercial seed lot	Seeding
Crownvetch	Coronilla varia	Commercial seed lot	Seeding
Shrubs			
Peachleaf willow	Salix amygdaloides	Limited commercial	Bare rootstock
Diamond willow	Salix rigida	Limited commercial	Bare rootstock
Sandbar willow	Salix exigua	Local cuttings	Bare rootstock
Yellow willow	Salix lutea	Commercial	Bare rootstock
Bebbs willow	Salix bebbiana	Local cuttings	Bare rootstock
Red osier dogwood	Cornus stolonifera	Commercial	Bare rootstock
Hawthorn	Crataegus chrysocarpa	Commercial	Bare rootstock

diversity to the plant community in this zone, but these species should only compliment and never totally replace the previously listed species.

TERRACE ZONE

The terrace zone includes the bank areas usually not exposed to river action except for occasional true flooding and the generally level land from the river landward. The undistrubed terrace zone is naturally an open gallery forest with many grassland species intermixed. When disturbed, this area has the highest potential for supporting vegetation and should be the easiest to revegetate. Disturbance will occur in this area from land based construction of erosion control structures. Graded slopes will cause different site capabilities to the level terrace areas since surface erosion and mass slumping could occur; consequently, the graded slopes must be properly protected. Drought, compared to flood tolerance on previous zones, will be the major factor affecting plant survival. However, if properly protected,and adequate rainfall, the terrace zone can provide a mixture of woody and grassland species that are vital in erosion control and important in wildlife habitat, esthetics and recreation.

Species selected for revegetating the terrace zone should consider the normal woody-plant successional sequence found in natural revegetation of stablized sandbars. Initially willows and cottonwoods will establish with a cottonwood forest developing. This is gradually replaced by boxelder and green ash forest and finally a green ash and bur oak forest.

Initial revegetation work should involve seeding grasses and legumes for a quick vegetation cover. Native grass species used on the terrace zone should include a mixture of reed canarygrass, creeping foxtail, western wheatgrass, little bluestem, big bluestem, switchgrass and Kentucky bluegrass. Crested and intermediate wheatgrass, redtop and smooth brome are tamegrass well adapted to this environment which could be added to the seed mixture to improve grass establishment. White and yellow sweetclover should be included in the seed mixture to help add soil fertility and excellent wildlife cover.

Trees and shrubs should be transplanted into the establishing grasses to re-establish the naturally occurring gallery forest. Cottonwood, green ash, boxelder, juniper, Rocky Mountain juniper and ponderosa pine trees should make up the backbone of the woody species used on the terrace zone. Willows can be included near the bank zone. Other woody species from Table 4 can be added to the community for diversity and cost reasons if desired.

SPECIAL SITES

Hardpoints and sand dikes: The top of hardpoints should have a similar environment to the terrace except the soil depth will be much less. Grasses and trees listed in the terrace zone (Table 4) should be suitable for this area. Sand dikes should be seeded to more flood tolerant grasses like reed canarygrass, creeping foxtail and prairie cordgrass.

Roadways and construction sites: Roadways, storage sites and related areas will require some revegetation if markedly disturbed in the construction phase. These sites usually can be selectively treated by following normal vegetative planting practices. These sites usually will be quite similar to the terrace zone, but specific plans should be developed for each individual site.

Table 4

SPECIES RECOMMENDED FOR REVEGETATING THE TERRACE ZONE

(Includes the hard points and dikes 1/)

SPECIES COMMON NAME	SCIENTIFIC NAME	AVAILABILITY OF PLANT MATERIALS	METHOD OF PLANTING
Grasses			
Reed canarygrass	Phalaris arundinacea	Commercial seed lot	Seeding, sodding
Creeping foxtail	Alopecurus arundinaceus	Commercial seed lot	Seeding
Quackgrass 2/	Agopyron repens	Commercial seed lot	Seeding or sodding
Western wheatgrass	Agopyron smithii	Commercial seed lot	Seeding
Crested wheatgrass	Agropyron desertorum or Agropyron cristatum	Commercial seed lot	Seeding
Intermediate wheatgrass	Agropyron intermedium	Commercial seed lot	Seeding
Streambank wheatgrass	Agropyron riparium	Commercial seed lot	Seeding, sprigging
Redtop	Agrostis stolonifera	Commercial seed lot	Seeding
Little bluestem	Andropogon scoparius	Commercial seed lot	Seeding
Big bluestem	Andropogon gerardi	Commercial seed lot	Seeding
Switchgrass	Panicum virgatum	Commercial seed lot	Seeding
Smooth brome	Bromus inermis	Commercial seed lot	Seeding, sodding, sprigging
Kentucky bluegrass	Poa pratensis	Commercial seed lot	Seeding, sodding
Legumes			
White sweetclover	Melilotus alba	Commercial seed lot	Seeding
Yellow sweetclover	Melilotus officinalis	Commercial seed lot	Seeding

1/ It is recommended that only grasses and legumes be used on the hard points and dikes.

2/ Weed - not allowable for sale in N.D.

Table 4 (cont.)

Trees and Shrubs	SCIENTIFIC NAME	AVAILABILITY OF PLANT MATERIALS	METHOD OF PLANTING
Hawthorn	Crataegus chrysocarpa	Commercial	Bare rootstock
Cottonwood	Populus deltoides	Commercial	Rooted cuttings
Quaking aspen	Populus tremuloides	Commercial	Rooted cuttings
Green ash	Fraxinus pennsylvanica	Commercial	Bare rootstock or container
Boxelder	Acer negundo	Commercial (limited)	Bare rootstock
Juneberry	Amelanchier alnifolia	Local Collection	Bare rootstock or seed
Choke cherry	Prunus virginiana	Commercial	Bare rootstock
Bittersweet	Celastrus scandens	Commercial (limited)	Bare rootstock
Nannyberry	Viburnum lentago	Commercial	Bare rootstock
American elm	Ulmus americana	Commercial (limited)	Bare rootstock
Woods rose	Rosa woodsii	Commercial (limited)	Root pads, root and stem cuttings
Honeysuckle	Lonicera tatarica	Commercial	Bare rootstock
Virgins bower	Clematis ligustifolia	Local Collection	Seeding
Virginia creeper 1/	Parthenocissus inserta	Commercial	Bare rootstock
Wild grape	Vitis riparia	Commercial	Bare rootstock
Bur oak	Quercus macrocarpa	Commercial	Container
Buckbrush	Symphoricarpos occidentalis	Local Collection	Seeding
Bullberry	Sheperdia argentea	Commercial	Bare rootstock
Juniper	Juniperus communis	Commercial	Bare rootstock
Rocky Mountain juniper	Juniperus scopulorum	Commercial	Bare rootstock
Russian olive	Elaeagnus angustifolia	Commercial	Bare rootstock & container
Silverberry	Elaeagnus commutata	Commercially limited	Container
Buckthorn	Rhammus davurica	Commercial	Bare rootstock
Skunkbrush	Rhus trilobata	Commercially limited	Bare rootstock
Ponderosa pine	Pinus ponderosa	Commercial	Bare root & container

1/ Common name is a problem in the trade because several different species are referred to as Virginia Creeper. This can be overcome by requesting material using the scientific name.

Seven:

Revegetation and Cultural Techniques

PLANTING DESIGNS BY ZONES

The project manager should recognize the differences in planting sites aligning the river bank. Often the different planting sites or zones intergrade one into another. These zones may be quite narrow in width or difficult to distinguish. Consequently, the entire bank should be treated as a unit, with a systematic arrangement of plants and treatment practices. The proposed treatments should be designed to maximize existing equipment, manpower and other resources. Proper care in the selection of planting stock and implementation of realistic planting practices is required. Most sites are difficult to treat when compared to agricultural lands. Thus, plant materials must be carefully handled to assure establishment and survival.

The entire slopes should be treated to furnish a maximum array of plants capable of providing proper ground cover for erosion protection, wildlife habitat, and to appeal to recreation uses. As much as possible, native species are recommended and designed to the sites where they are best adapted. Sufficient numbers of plants and combinations of species will be used to allow for natural selection to occur. This will better assure the development of a suitable composition of species in a natural community.

SPLASH ZONE

This area cannot be successfully planted by direct seeding since this area will be inundated most of the year. Transplanting adapted species during low water release periods is the most practical approach. Transplanting aquatic species as "reed rolls", a system reported and described by Seibert (12), is recommended. This practice is shown diagramically in Figure 8. In addition, rhizomes, sod or clumps of adapted species could be systematically transplanted into this zone to develop the community. The reed rolls and other transplants must be held in place using mechanical or supportive structures until the plants are well established. Refer to the following sections for instructions in preparing, planting and anchoring reed rolls, sodding or sprigging.

The splash zone will be subject to flooding and scouring by river action. Serious,prolonged flooding can destroy newly established plantings or scouring by the river may remove transplants prior to adequate rooting; therefore, a followup treatment may need to be considered or planned as part of the contract to establish the vegetation.

BANK ZONE

Sites near the water's edge should be protected to prevent erosion by wave action. If only mild wave action is anticipated sodding of flood tolerant grass species like reed canarygrass should provide a rapid bank stabilization. Usually the sod must be held in place with small wooden pegs or wire netting until the sod roots adequately. High quality sod can root in 2 to 3 weeks. If more severe erosive action is anticipated the slopes should be further protected using a combination of supportive measures. Supportive measures that have performed adequately in similar areas include willow barriers, fascines, wattles and pav-

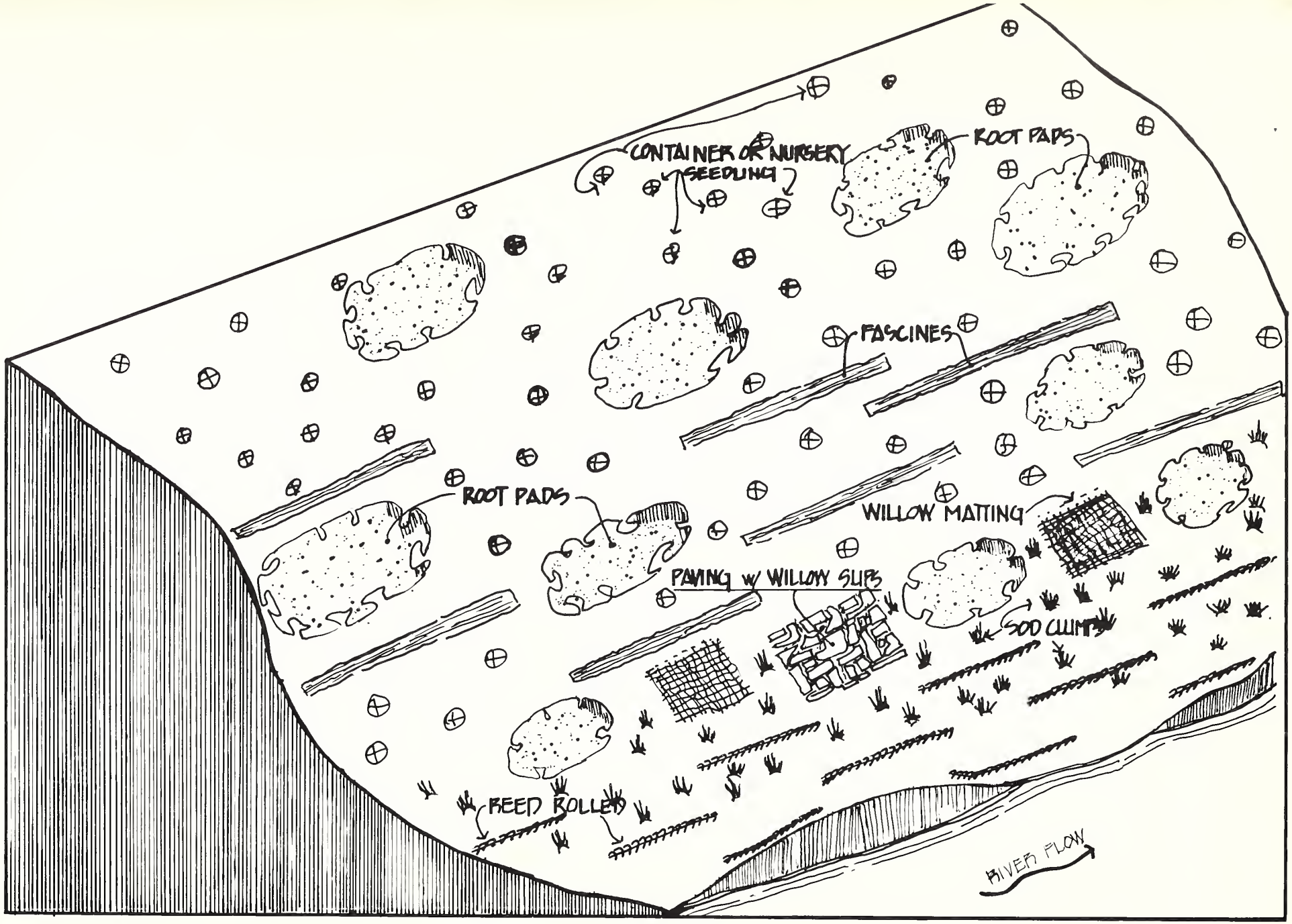


Figure 8: Planting Design for Streambanks

ing with willow slips between stones. Refer to the following section (pages 33-37) for a more detailed description of each supportive measure and Figure 8 for a conceptual planting design including these devices.

Gentler sloping sites on which wave action is not anticipated can have grasses direct seeded, but grasses established from seed require one to several months to develop erosion resistant stands. Therefore, supportive measures will be necessary on a greater percentage of the bank zone if seeding, rather than sodding is done. Stronger sloping sites like 1 vertical to 3 horizontal and 1 vertical to 1 horizontal sites must have an erosion control blanket or mat installed following mulching to reduce erosion. Similar treatments are suggested for more gentle slopes also. Woody plants can be transplanted onto protected sites with little disturbance to the mat or seedbed. However, direct seeding and mulching should follow transplanting of woody species where supportive measures are to be installed since the installation of these measures disturbs more of the plant area.

TERRACE ZONE

Generally the terrace zone should be revegetated using direct seeding and transplanting. The level terrace or graded slopes less than 1 vertical to 5 horizontal should require few vegetative structural measures to protect the areas from erosion. Small, one-year-old seedlings or container stock can be used in transplanting woody species on this site. Trees and shrubs should be systematically planted about 6 to 10 feet apart utilizing the complex of species recommended .

Sites with steep slopes, greater than 1 vertical to 3 horizontal, will need erosion control measures. Surface netting and mulching should be used to assure seedling establishment. Utilizing larger size transplants of woody species should be considered also. Supportive structures or sodding may be required in more severe situations such as 1 vertical to 1 horizontal slopes, heavy traffic areas, etc. Where surface drainage is causing gully erosion on the bank slopes a small furrow should be dug along the break of the terrace to divert or control the water.This ditch or furrow could be used to plant woody shrubs and trees, sodding of this trench may be necessary to prevent erosion.

PLANTING DATES

Direct seedings of herbaceous materials (i.e., grasses) made in late fall after October 15 are generally more successful and will be encouraged. Some grass competition will occur with shrubs and trees planted the same fall or the following spring, but it will not become a major limiting factor to shrub-tree survival and long-term growth. Revegetation schedules where woody species are planted more than 1 year after grass will be discouraged as a normal planting practice.

Plantings of native shrubs will generally be most successful when completed in the early spring before plant dormancy is broken. Nursery bare-root stock usually becomes available in mid-April (unless lifted from beds during the preceeding fall and kept dormant in cold storage) so planting can begin shortly afterwards. Snow, ice and mud will probably prevent earlier planting dates. Planting of woody species may extend to June 1, if planting stock is properly handled and if moisture conditions remain favorable on planting sites. When container stock material is used exclusively, the planting period can

extend throughout the summer months.

Although fall plantings of woody species are also effective, the inavailability of bare-root nursery stock during this period will limit any large-scale efforts. The excavation and placement of root pads and wildings may occur in the late summer or fall after plant dormancy has begun and when construction work associated with structural modifications of streambanks is in progress (i.e., machinery is most likely available to do root padding).

Table 5 gives a summary of planting date considerations for woody species as related to this project.

TABLE - 5 PLANTING DATES

1. Bare root nursery stock and dormant wildings.
   a. Spring-April 10-May 15 (approx)
   b. Fall-October 1-October 30 (approx)
2. Container grown
   a. Dormant stock handled as spring bare-root.
   b. Nondormant - after danger of severe frost has passed (May 21) until freeze up (October 30).
3. Root Pads and Wildings collected when in full or partial leaf.
   a. Preferably as dormant but some site specific species may require other times. August 15 to September 15 is recommended in order to allow time for some root growth before freeze up. This method is more time critical and care-critical than any other method and would require more supervision. It is recommended only where the other methods are not feasible.

DIRECT SEEDING OF HERBACEOUS SPECIES

Site preparation needed for seeding is minimal when topsoiling is practiced. Some tillage to reduce the compaction by heavy equipment used in topsoiling may be required. To prevent extensive mixing of subsoil materials with topsoil, tillage treatments should not extend deeper than the topsoil bottom.

Optimum establishment of seeded grasses in a droughty environment requires the placing of seed beneath the soil surface so that good seed-soil moisture contact is made during the germination stage. Therefore, it is desirable on all 1 vertical to 8 horizontal and 1 vertical to 3 horizontal slopes and on terrace areas to seed by drilling where practical or to use special equipment to get proper seed placement in the soil surface. Generally, seed will be sown at an approximate depth of 3/4 to 1 1/4 inches in the sandy loam soils typical of the treatment area.

Hydroseeding can be an effective method of broadcast seeding on the steeper 1 vertical to 1 horizontal slopes or possibly the entire area. Areas to be hydroseeded must first be lightly harrowed to incorporate the broadcasted seed and to help grass become established. Mulches will be applied following the seeding to reduce soil moisture loss and to tie down and cover seeds and reduce immediate surface soil erosion by wind and water.

The source of seed must be considered when purchasing seed. Tame grasses like reed canarygrass, creeping foxtail and Kentucky bluegrass and the legumes can be obtained from sources

where available; however, seed of natively adapted species like western wheatgrass, little bluestem and big bluestem should be obtained preferably within a 200 mile radius of the planting site. Seed lots selected will be approved by the Corps of Engineers. Noxious weeds will not be a part of the seed lot.

Suggested seed mixtures and seeding rates for the bank and terrace zones are shown in Table 6. Seeding rates are based on approximately 100 seeds/ft^2 of pure live seed (PLS). Pure live seed concept assumes that each pure live seed is capable of producing a viable plant if given proper environmental conditions. Pure live seed is calculated by the following formula:

$$\% \text{ PLS} = \frac{(\% \text{ germination}) \times (\% \text{ purity})}{100}$$

If the PLS of a seed lot is less than 95 percent, the seed quantity used to compound the suggested species mixture should be adjusted upwards by dividing the suggested rate by the PLS. For example, if reed canarygrass seed lot has a 80 percent germination and a 95 percent purity, the PSL would be 76 percent (80 x 95 ÷ 100) and the seed quantity used in the seed mix for the bank zone would be about 4 pounds. The seeding rate/acre of the mixture is increased proportionally to the increase caused by the PLS adjustment. Number of seeds per pound and recommended seeding rate for individual species of selected grasses and legumes are given in Table 7.

Table 6 Recommended seed mixture and seeding rate for bank and terrace zones.

Bank Zone

Species	Seed PLS lbs/acre	Minimum Germination 1/
Reed canary grass	3	80%
Creeping foxtail	2.5	85%
Crownvetch	2	90%
Sweetclover	2-3	90%
	9.5-10.5 lbs/acre	

Terrace Zone

Species	Seed PLS lbs/acre	Minimum Germination *
Reed canary grass	2	80%
Creeping foxtail	1	85%
Western wheatgrass	2	80%
Little bluestem	2	50%
Big bluestem	2	50%
Switch grass	1	80%
Kentucky bluegrass	1	85%
Sweet clover	1-2	90%
	12-13 lbs/acre	

1/ Seeds with germination rates less than the minimum germination rates should not be used.

MULCHING

Mulch is essential to protect seed and soil from eroding off sloped banks, particularly on the upper, steeper portions.

Straw or clean grass hay should be applied uniformly over the banks at a rate of 3,000 pounds per acre through the use of "Finn" type mulch spreaders. Hay and straw material will be free of mold, fungus or weed seed. Lincoln Oakes Nursery of Bismarck has agreed to make available some surplus grass hay for this purpose. The hay contains a seed component of several of the grass species chosen for this project which may provide an additional benefit.

Woven mesh or net-type mulches are generally effective and should be considered a viable option on steeper bank slopes. The 3 to 4 foot wide rolls can be attached to these areas by healing the net top into the soil and by using fabricated staples placed at specified intervals. The combination of "Jute" type net and straw is effective in arid areas.

Artifical fiber-type mulches should be discouraged since they are usually ineffective in most situations except where irrigation is provided.

SOD PLANTING

Sod planting is a practice in which sections of grass or herbaceous plants are lifted from existing beds and transplanted to the disturbed sites. Small sections or plugs 2-4 inches in width and 4-6 inches in length can be dug and lifted from wild-land sites or nursery or greenhouse grown. Many species are well adapted to this method of planting. The plugs are placed in pits at a depth which allows the aerial organs of the plant to be exposed. (Figure 9)

Large rolls of sod can also be lifted and field planted on areas where surface stability is most critical. Stakes will be used to assist in securing the sod to the slope until the plants become rooted. Sections of sod can be dug or lifted from native plant communities using large diggers, frontend loaders, backhoes, etc. The sod or root mass is then transferred to the planting site and planted.

REED ROLLS

Reed rolls are constructed by grouping and planting transplant section of sod, rhizomes and shoots. Various species can be planted in this manner. Slips are taken from existing beds during the inactive season. Rhizomes and shoots are removed and pruned to insure the use of healthy material. A trench approximately 16 inches in width is dug into the bank; wire netting is stretched across the trench; coarse gravel, sods or the reed-clumps are placed in the net; the wire is then drawn around the material and tied with wire. A row of stakes are placed below the roll and attached to the wire to provide stability. For further directions, refer to Seibert, 1968 (12) and Figure 10.

SPRIGGING

Sprigging (see Figure 11) is applicable in wet and moderately wet zones, using the suitable species shown in Tables 2 and 3. All species should be planted at a rate of approximately 40 sprigging bushels per acre. Aerial organs of plant colonies such as reeds or grasses are scythed, and then rhizomes and shoots are carefully removed from the soil. They are placed in holes or narrow trenches, so that only the aerial sprouts are above the soil. (Seibert 1968). (12)

Table 7 Number of seeds per pounds and seeding rates for grasses and legumes recommended for revegetation.

SPECIES		Seed/lb	lb/Acre
Grasses			
Giant mannagrass	Glyceria grandis	NI	NI
American mannagrass	Glyceria striata	NI	NI
Reed canary grass	Phalaris arundinacea	524,670	6-11
Creeping foxtail	Alopecurus arundinaceus	NI	NI
Northern reed grass	Calamagrostis inexpansa	NI	NI
Prairie cordgrass	Spartina pectinata	NI	NI
Quack grass	Agropyron repens	242,550	7-13
Western wheatgrass	Agropyron smithii	NI	NI
Crested wheatgrass	Agropyron desertorum and Agropyron cristatum	172,265	6-12
Intermediate wheatgrass	Agropyron intermedium	86,265	8-12
Streambank wheatgrass	Agropyron riparium	153,562	6-12
Redtop	Agrostis stotonifera	4,192,031	5-10
Little bluestem	Andropogon scoparius	133,875	10-20
Big bluestem	Andropogon gerardi	162,422	11-15
Switch grass	Panicum virgatum	382,922	5-8
Smoothbrome	Bromus inermis	108,281	5-15
Kentucky bluegrass	Poa pratensis	2,142,984	15-25
Legumes			
Crownvetch	Coronilla varia	108,281	15-20
White sweetclover	Melilotus albus	255,455	10-15
Yellow sweetclover	Melilotus officinalis	255,938	10-15

N I = No information

FASCINES AND WATTLES

Fascines are lengths of switches or stems of willow or other sprouting species packed together in a tight continuous roll 10 to 60 feet in length and 4 to 5 inches in diameter. They are buried across a slope at regular contour intervals and are supported on the downhill side by stakes set at right angles to the slope (see Figures 10 and 12). When applied to slopes, fascines provide an effective deterent to downhill surface movement of soil caused by downward water flow, wind action, trampling of wildlife and livestock and the forces of gravity. In addition, sticks of such species as willow used in the fascine have the ability to sucker and set roots which can help stabilize the soil.

Fascines will be built from 2 to 3 year old willow switches or switches from similar species, 4 to 6 feet long and held together in a tight roll by wire. Stakes will be at least 30 to 36 inches in length, 1" x 1" in thickness and spaced at 15 to 18 inch intervals. For steeper slopes, every fourth or fifth stake driven will be 40 to 48 inches in length and 2" x 2" in thickness. The entire roll will be attached to the stakes with galvanized wire before the stakes are pounded to a depth where only 3 inches protrudes from the ground, or where the fascine is held firmly in place. Fascines can also be held in place by living willow cuttings called "wattles" which are used in place of some of the stakes.

Numerous rows of fascines should be set at 3 to 4 foot intervals. Each fascine will be lightly covered with earth so that branches are only partially covered up. In this manner, sprouting will be encouraged.

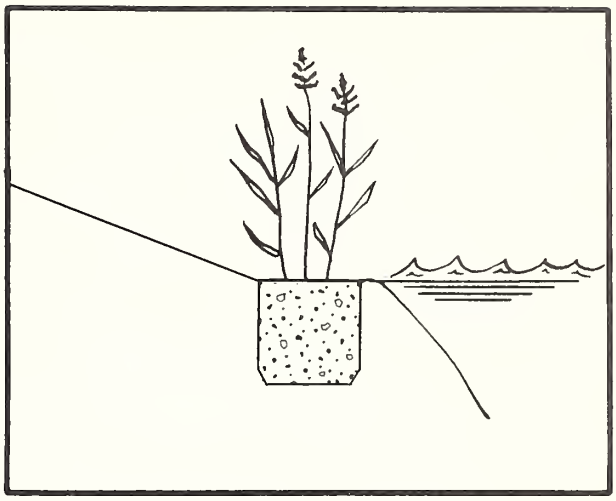


Figure 9: Sod Placed in a Pit [12]

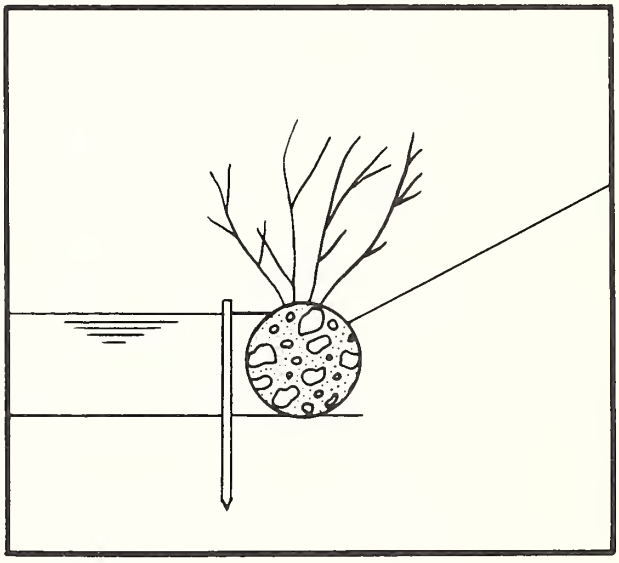


Figure 10: Planting of Reed Roll [12]

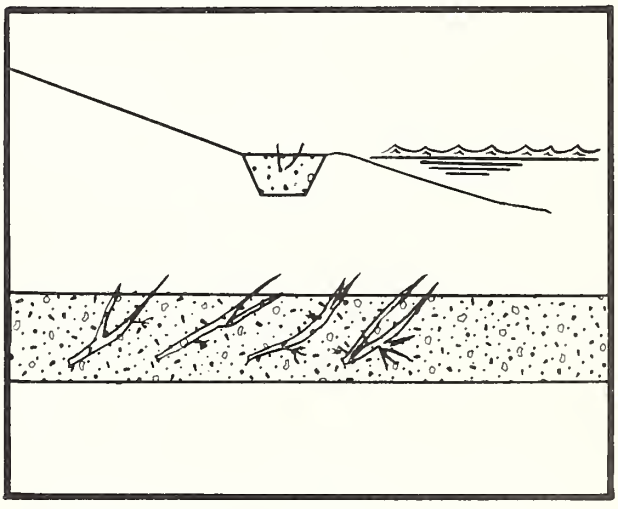


Figure 11: Sprigging [12]

BARRIERS

Barriers, made by interlacing willow shoots, are used in areas where stream erosion may uproot small transplant stock. Seibert, 1968 (12) provides the following guides in the construction and use of willow barriers:

"The barriers are made of willow switches 2 to 3 years old and 4-3/4 - 6-1/4 feet long which are placed at intervals 0.4-0.6 inches, perpendicular to the current or sloping downward. They are set in a trench 6 inches deep, which is filled in afterwards."

"The spread willow switches are held in place by wire, by fascines or by willow hurdling. Before the switches are set out, the stakes, 1-7/8 - 3-1/4 feet long, needed for the wire and for fixing the large hurdles to the ground, are driven in so that 4-8 inches are still showing. After setting up the switches, the stakes are wired together with galvanized wire, then again driven home until the switches are firmly held to the ground---."

"The whole barrier is lightly covered with earth; so that the branches are set in earth but not completely covered up."

ROOT PADS

Large clumps of shrubbery commonly referred to as "root pads" will be used on a supplemental basis, where practical, in splash, bank and terrace zones of the bank. Clumps of species such as willow, red osier dogwood, cottonwood, rose, hawthorne and silver buffaloberry are well suited for this purpose.

Front-end loaders or "Veimeer" type spades are well suited for the excavation and placement of root pads. Placement on slopes greater than 1 vertical to 6 horizontal should

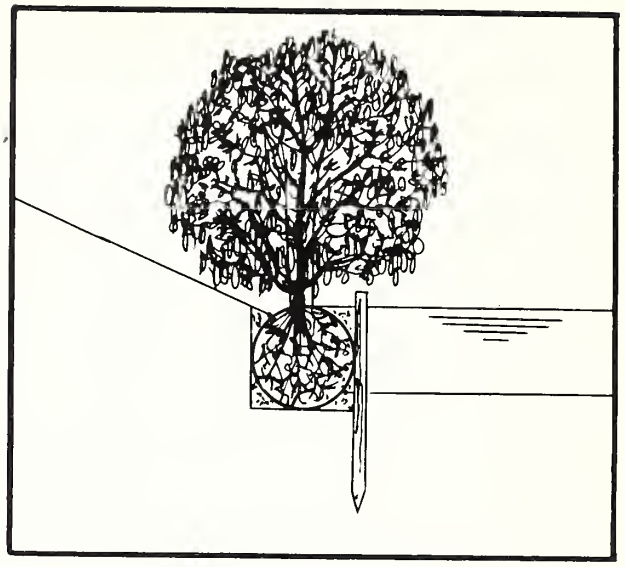


Figure 12: Fascines [12]

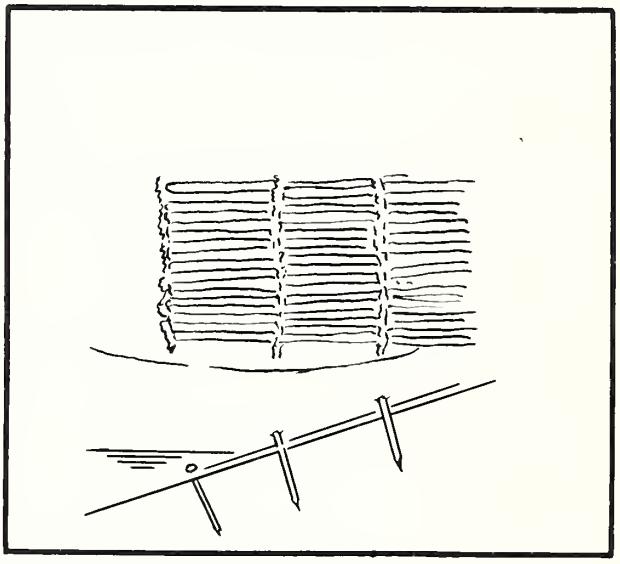


Figure 13: Willow Barriers [12]

include securing the root pads by driving 2 inch diameter, 18 to 24 inch long wooden stakes through the pads at 2 to 3 foot intervals. Potential source areas of root pads include the following:

(1) construction sites where pads of vegetation can be removed and stored for future use, (2) where private landowners will allow removal of pads from adjacent sites, assuming no permanent degradation will occur to those lands, and (3) nearby lands owned by the Corps of Engineers and managed by the North Dakota Department of Fish and Game.

FERTILIZATION

Fertilization of herbaceous species can be incorporated into the hydro-seeding slurry application (seed, water and fertilizer) applied in the late fall. When using fertilizers in a hydro-seed slurry, initial application rates should not exceed 15 lbs. of actual Nitrogen (N) per acre. This low rate will prevent the excessive concentration of salts in the slurry solution which is damaging to grass seeds.

Additional follow up applications of fertilizer on the treatment sites will be made for the first few years after seeding in order to encourage establishment and promote a heavier grass cover. Such applications can be made in the late fall or early spring at a rate of 40-50 lbs. of actual N per acre. Maintenance fertilization treatments at similar rates will probably be necessary every 3-5 years. The use of high phosphate fertilizers are encouraged.

Initial treatment of individual woody plants by using fertilizer "starter" tablets are generally effective and should be used. One 9-gram tablet per plant is considered adequate. Tablet fertilizer formulations that are low in N and high in phosphate are more desirable because they tend to promote greater root growth and less top growth during the first few years of establishment. This is important for plant survival and for holding soil in place.

Eight:

Plant Procurement and Costs of Woody Species

PLANT PROCUREMENT

Commercial availability of the plants discussed as being native or suitable for the areas under discussion have been listed on pages 23-25 . Many of the species are not readily available without special emphasis. Attention must be paid to seed sources in order to have winter hardy material (genetically adapted to site). A partial listing of suitable nurseries is in the appendix. More detailed lists are available from the North Dakota State University plant source book or Association of American Nurseries, 230 Southern Building, Washington DC.

Special propagation of selected plant material is necessary, since many of the site specific species are not readily available from commercial sources. Plans for plant procurement must be made as soon as possible in order to be sure of a source. Nurseries need lead time. The nursery selected or contracted to grow the material must either collect seed from suitable plants in the wild (and not every year is a seed year) or collect plants from the wild and grow them under controlled conditions until the planting season. Container grown material from a greenhouse is another alternative to nursery grown bare-root material or wildings and should not be overlooked when contracting for the plant material. Native plants are not as common in the trade because of the difficulty in growing them. The idea of phase planting must be considered in order to give the areas a mixture of plants. This means planting as soon as possible, either during or following construction as soon as some plant material is available and coming back with additional species (and perhaps replants, if needed) as they become available. In the zone most subject to inundation, consideration should be given to a larger grade of plant material (up to 4'). The other material should follow the size specification recommended in the "Tree Planting Handbook for the Dakotas" (30).

PLANT HANDLING

Many mechanical contractors do not understand the necessity of careful attention to the details involved in the care and handling of live plant material and the scheduling of the necessary steps. Close communication betweem the nursery, the transportation system used by the contractor, the planting personnel, the contractor himself and the contract administrators and inspectors is necessary to insure that live plant material in optimum condition is placed in properly prepared sites. Plant handling varies with the contractor and type of material, i.e., refrigerated vans on site for the entire planting job to twice daily pick up at the nursery in enclosed carriers. Care of material also varies greatly because of the species, whether bare-root or container grown. There is a difference between container grown and containerized.

Consideration should be given to various alternatives in the process of "who does what."

A contract for the entire project including revetment work, planting stock procurement, and installation, or:

A contract for revetment and installation with a separate plant procure-

ment contract or:

Separate contracts for all three phases of the project. Maintenance of the planting should be considered to insure establishment. Chemicals are probably too environmentally hazardous to use. Hand noxious weed control will be expensive but may be occasionally necessary. Planting more seedlings per acre may be the most practical, thereby letting natural selection occur.

Plant losses can come from animal damage, ice damage, inundation, as well as competition or failure of the seedling to grow. Close communication between the grower or supplier of planting material and the Corps is critical due to replanting needs, changes in methods or species, construction delays or planting stock problems at the nursery.

ESTIMATED STOCK COSTS (see Table 8)

The variation in price is subject to plant numbers desired, availability of species, seed, method of propagation, nursery overhead, etc. A cost of planting stock can be estimated when species, numbers, etc. are selected for a specific site.

Transportation costs are usually figured at 20 percent of cost of plant material. Planting stock costs for bare-root nurseries (Government) range from $26/M to $80/M for mostly coniferous species. Container costs range from $40/M to $500/M depending on the location of the facility, size of container, amount of time in the container and the species.

Planting costs for bare-root range from the basic 5 cents per plant upwards to 15 cents.

Container planting costs for hand planting range from ½ the cost of bare-root seedlings to costs equal to or exceeding the cost of the container seedling. Two hundred to 400 plants per person day can usually be planted.

Table 8 ESTIMATED PLANTING STOCK COSTS FROM VARIOUS SOURCES 1/

Type of Plant Material	SOURCES			
	Government	Private	Wilding	Contract
	Cost per plant			
Bare-Root 15" - 24" Min. Size	$0.08-$0.18	$0.10-$0.36	$1.00-$1.50	$0.08-$1.50
Container Grown 2" x 2" x 8"	$0.40-$0.50	$0.50-$1.50	N/A	$0.50-$1.50
Larger Container	N/A	$1.50-$7.50	N/A	$1.50-$7.50

1/ These are estimated based on averages.

Nine:

Monitoring and Evaluation

DIRECT DOCUMENTATION OF EROSION PROTECTION

AERIAL PHOTOGRAPHIC MONITORING

Each engineering structure (i.e., revetment, hard point, etc.) should be monitored for erosion directly by use of aerial photogrammetric techniques. This will allow evaluation of changes occuring at the land water interface providing the procedures discussed below are used.

Aerial photo coverage must be flown at least twice a year. Suggested times are in the spring and in the fall. Photo flights should be highly controlled; that is, the scale of repeated flights must be the same. To allow comparisons of repeated photo coverage, flights must be made during low water periods and when river water levels correspond to each other. Overlays can be made on the photos which will delineate the water-interface boundary. Subsequent overlays can be compared showing any changes in the water-interface boundary (see Figure 14). Photogrammetric measurements can then be made on the overlays to determine amount of surface area lost to erosion.

GROUND PHOTOGRAPHIC COVERAGE

The above aerial photo coverage should be supplemented by ground photos taken at established photo points with photos taken periodically for a given azimuth. These must be taken at the same time the aerial photos are taken; however, others can be taken at intermittent times if deemed necessary.

OCULAR DESCRIPTION

As a further effort to document erosion, a description of any erosive processes must be made at the same time the ground photos are made. Processes that must be documented and particularly noted include such things as slumping, rilling, gullying, wind erosion and wave action. Descriptive estimates of degree of severity for each of the above processes per engineering structure will be made.

INDIRECT DOCUMENTATION OF EROSION PROTECTION

Erosion protection is assumed to be offered by the vegetation if the plants are surviving and developing; that is, covering the site. The development of the vegetation needs to be monitored and possibly correlated, at least from a visual standpoint to the degree of erosion or lack of erosion taking place on the treated streambank. One would assume, for example, that vegetative plantings are doing a good job if the vegetation is growing well in all elevation zones on the revetment structure and aerial/ground reconnaissance indicate no erosion is taking place.

WOODY PLANT SURVIVAL AND VIGOR

Woody seedlings (rooted transplants) will be monitored for survival and vigor in each elevation zone on the treated streambank. After planting, 10 percent of the woody seedlings in each elevation zone will be systematically selected and marked with a stake. Each marked plant will be revisited periodically to determine whether it is alive or dead and observe its vigor of growth. Percent

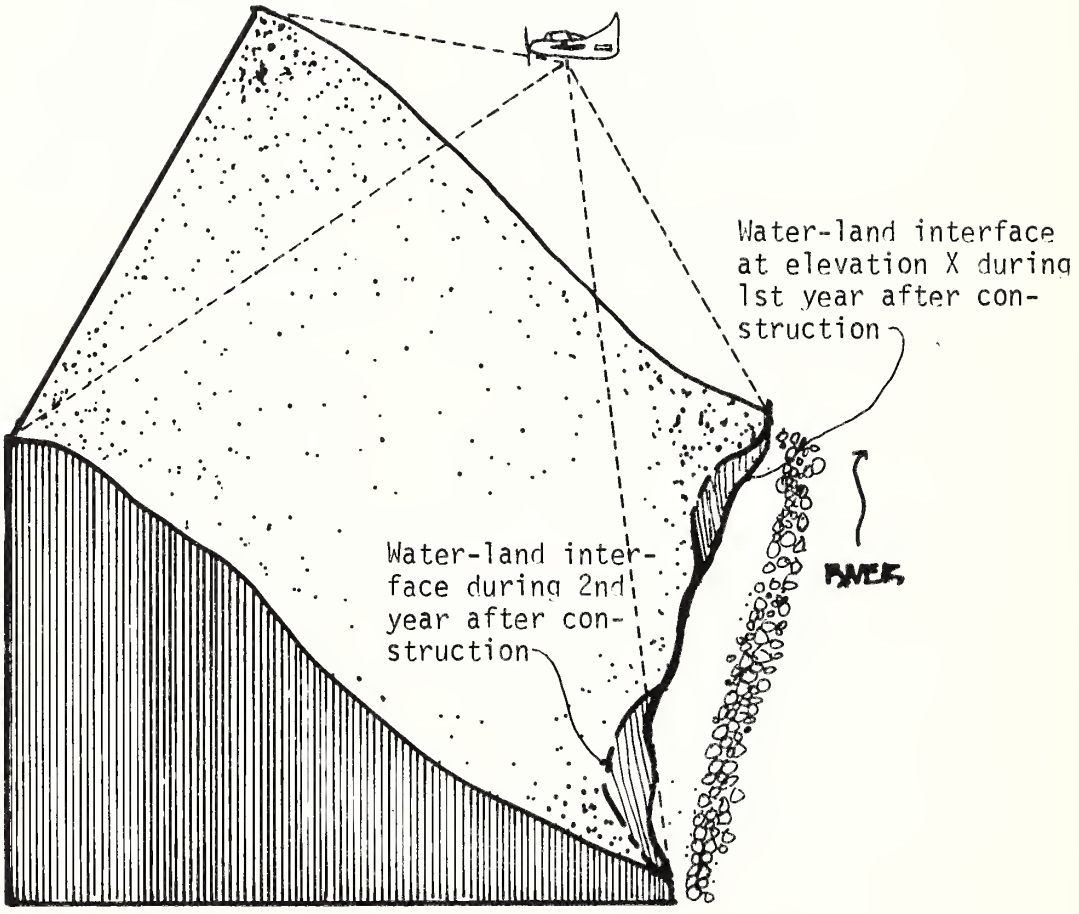


Figure 14: Aerial Monitoring

survival can be determined by dividing the number alive by the original number staked. Vigor can be determined subjectively by assigning each live plant a vigor class which is shown below:

a. Plant growing vigorously (new growth, green stem and leaves, no yellowing of leaves) - Class 3.

b. Plant is growing, but stable (no new growth, just green) - Class 2.

c. Plant is declining in vigor (stem deteriorating, leaves dropping, yellowing of leaves) - Class 1.

The frequency of monitoring plant survival must be a minimum of once a growing season (probably near the end of summer) for three consecutive years. Preferably monitoring will be done at a frequency of twice a growing season (once in the spring and once near the end of summer) for 3 years.

GROUND COVER AND STEM DENSITIES

A measurement of ground cover is periodically needed to determine if the herbs, particularly, are spreading successfully across the site. Measurements of stem densities are needed to determine if woody cuttings and fascines are sprouting and adding to the vegetative composition and density. Both of these factors can be measured by establishing 1 square meter plots randomly throughout each elevation zone until a 1 percent sample is achieved. These plots must be permanently established immediately after planting and delineated by well-marked stakes.

Ground cover for each plot will be determined by using ocular estimates divided into cover classes as described below. Each cover class will be assigned a number and recorded on the data sheet for that plot. Only live vegetation will be considered and the individual must rely on his visual estimation.

CATEGORY DESCRIPTION (% Live Cover)	NUMBER OF CLASS
1	1
1-9	2
10-24	3
25-49	4
50-74	5
75-100	6

Once percent ground cover has been determined for each plot, composition by dominant species will be estimated. A list of the dominant plant species for each plot will be prepared.

Stem densities of woody plants must be determined by species for each plot by counting the number of stems. This will give an estimate of number of stems per species per square meter.

The recommended frequency of monitoring for ground cover and stem densities is the same as that described for woody plant survival and vigor.

WATER LEVEL MONITORING AND DOCUMENTATION OF FLOODING

It is highly recommended that water levels be monitored by continuous recording gages since the success of the vegetative plantings is dependent upon the degree of flooding.

PROPOSED PROCEDURE

It is suggested that three Fischer-Porter continuous recording water level gages be placed on the 80-mile reach of river between Garrison Dam and Bismarck. One gage will be placed on the upper reach, one in the middle reach, and one on the lower reach. Gages have the capability of continuous recording for 1 month before the tapes and batteries must be

changed. The U.S. Army Engineer Waterways Experiment Station (WES) has the capability of taking the output from such recorder-gages and inputting its tape into a water level reader which converts the water level data into computer input on keypunched cards. Output is in the form of bargraph charts showing percent duration of inundation based upon any designated time increment.

Water level monitoring in conjunction with the monitoring of plant survival and performance gives a better capability of determining if plants were impacted upon by frequency and durations of flooding.

It is believed the above direct (aerial/ground reconnaissance) and indirect (plant survival and performance) methods of documenting and evaluating the success of the plantings will, in concert, give a good evaluation procedure.

SPECIAL MONITORING

The procedures for monitoring already documented will give a quasi-quantitive way of determining success or failure of each site receiving vegetative treatment. However, these procedures do not provide the means of quantitatively (statistically) determining which plant species will perform best in such situations nor do they provide the means of determining which planting technique (i.e., supported vs. unsupported vegetation) provides the most rapid plant cover for the least cost.

It is therefore recommended that the Omaha District consider an additional option of allocating part of a revetment (preferably 500-600 linear feet) for an experimental planting and monitoring effort which is conducive to a statistical analysis. Such an experiment would allow probability statements to be made about performance of certain plant species versus others and about certain planting techniques versus others.

In general, it is envisioned that the experimental designs of the field plots will be tested in four parts of of the revetments. One revetment will be used as a control. Three other revetments will have three plots each delineated by elevation zone. Field plots would be arranged in a way to allow a statistical analysis of which plant species in each elevation zone performs well and of what planting treatment gives the best results.

If the above option is given serious consideration by the Omaha District, a more detailed plan of study with experimental design will be presented at a later date.

Appendix

Partial Listing of Nurseries

Possible nursery sources for planting stock needed for Missouri River bank stabilization include the following:

North Dakota State Forest Service
Nursery
Towner, ND

J&N Nursery
Sheldon, ND

Lincoln-Oakes Nurseries
Bismarck, ND

Clarkdale Nurseries
Milbank, SD

Gurney's Seed & Nursery
Yankton, SD

Big Sioux Nursery
Watertown, SD

Lee Nurseries
Fertile, MN

Lawyer Nursery
Plains, MT

Bailey Nurseries
Saint Paul, MN

Smith Nursery
Charles City, IA

Plumfield Nursery
Fremont, NB

Colorado Forest Service
Fort Collins, CO

Native Plants
Salt Lake City, UT

Montana Division of Forestry
Missoula, MT

Kester's Wildgame Nurseries, Inc.
Omro, Wisconsin

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